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ABSTRACT

Having K-12 students create artifacts can serve several purposes within an effective science curriculum. Through World Wide Web (WWW) publishing projects, students' cognition and motivation can be improved and the "authenticity" of their work increased, relating to recent thinking about situated learning and constructivist science teaching. To have authentic value for someone else, student work must be a somewhat unique contribution to the WWW, done with a particular audience in mind, and done at a high enough level of expertise that it can be seen as valuable by outside readers. Learning to communicate with other scientists is an important part of learning to do science, and the specific forms of disciplinary communication reflect the underlying sociocultural purposes of science. A range of instructional supports was developed to help students bridge the gap between themselves and authentic outside audiences: (1) genre explanations provided by teachers regarding the needs of readers, (2) students write and publish WWW reviews of existing resources, (3) surveys of audience knowledge, (4) peer review, and (5) comments from outside readers. (Contains 16 references, a 6-question Likert survey is appended.) (CR)

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Student publishing in a WWW digital library- goals and instructional support

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Student publishing in a WWW digital library- goals and instructional support

Three purposes for artifacts

Having students create artifacts can serve at least three purposes within an effective science curriculum.

1) Artifact can serve as a representation of the internal understanding of the student(s). The knowledge that is inside a students head is somehow represented in a tangible form (a report, a science fair project, a multimedia resource.) and students are evaluated on the depth or accuracy of these representations.

2) Artifact can serve as 'projects'. The end product may or may not exactly mirror the students' internal understanding, but students are presumed to learn in the process of constructing the artifact, because the artifact helps sustain attention on abstract content matter (Blumenfeld, et al., 1991; Keys, 1994), or because while constructing the artifact students learn transferable skills of design (Carver, Lehrer, Connell, and Erikson, 1992; Kafai, 1996).

3) Artifacts can serve as a basis for **communication.** Students create artifacts which are crafted for a social purpose, and exist within some kind of social space. These artifacts are drawn from student knowledge, but this knowledge is also reshaped, reexamined, and selected for the purpose of communicating with a certain audience.

Although the artifacts we will report on also serve the first two purposes, we are chiefly interested in studying how this third purpose, communication, affects the cognition and the motivation of high school student artifact-designers. Recently, the developing technologies of telecommunications has dramatically expand the potential audiences for student work. The first author's dissertation work encompasses two projects where students published three kinds of artifacts on the World-Wide Web, for a potentially worldwide audience. We are examining what the potential benefits of this kind of publishing are for students, and what instructional supports may help students design with outside audiences in mind.

The two projects we refer to are both accessible on-line.

Air pollution laboratory reports [http://chs-web.neb.net/pollution]

Multimedia resources on infectious diseases [http://chs-web.neb.net/diseases]

Goals: why publish student work on the WWW?

Throughout our WWW-publishing projects, there are two classes of benefits we have been trying to achieve, one more philosophical and one more practical. The first class of benefits, improving student cognition and motivation through increasing the 'authenticity' of their work, relates to recent thinking about situated learning and constructivist science teaching. Secondly, and more pragmatically, we are interested in teaching the specific communication forms that scientists use, within a more meaningful context.

Authenticity

Our research draws upon recent calls for more authentic types of instruction (Newmann, 1991; Resnick, 1987). Our ideas about authenticity fall into two categories: authenticity of cognition and authenticity of motivation. In terms of cognition, an 'authentic' task is connected to tasks that are performed outside of school (Lave & Wenger, 1991) is usually complex and involves some higher-order thinking, and is often based loosely upon tasks performed by professional scientists. (Songer, 1997). WWW publishing may be cognitively authentic in that it involves representing content for communication with an outside audience. In terms of motivation, an 'authentic' task is one that students see as connected to their life, and that they value. We hope that by publishing student work on the WWW we are giving students a social purpose for conducting their research, and they will be motivated by the chance to connect their work with people in the larger WWW community.

There are, of course, difficult questions associated with these somewhat vague claims of authenticity. In this paper we will mainly address one of the first such problems we encountered, which was, What can K12 students publish that is truly an 'authentic' contribution to the WWW?

Making a publishing project 'authentic' means more than just taking a normal class assignment and posting it on the WWW. Often, this would result in having 30 students publishing essentially the same assignment, which would not be seen as valuable either for students or potential readers. Authenticity also requires more than letting students create individually differing constructivist, multimedia 'artifact' and putting it on the WWW. In order to have authentic value for someone else, student work must be a somewhat unique contribution to the WWW, should be done with a particular outside audience in mind, and should be done at a high enough level of expertise that is can be seen as valuable by outside readers. In high school science, where curriculum must usually be matched with some sort of state or district objectives, the subject area must also meet these requirements.

We have used three types of WWW publishing artifacts which can be authentic contributions by HS students.

• Results of students' own scientific data collection and research. Students can make an authentic contribution to scientific knowledge by collecting and publishing new data. In our air pollution project, students measured pollutant levels on local streets, building, and parking garages, and reported their results in a lab report type of format. The local nature of this data was what made it authentic for both students and outside readers.

• Multimedia resources on specialized topics. More traditional types of 'reports', where students collect and synthesize information from secondary sources, can be authentic if students tailor their reports for specific purposes and audience, and report on topics that are somewhat specialized. In the infectious diseases project, students chose a specific disease and created multimedia resources that included more technical information than most documents for lay persons might have, but were less technical than the medical resources they found on the WWW, thus 'adding value' to their secondary source material by tailoring stacks to a new audience. Students also created new multimedia repeesentations (graphics, animations) of information they found. These resources might be authentically valuable for other high school researchers, or other lay persons with a scientific bent.

• 'Value-added' reviews of existing resources. Students can critically evaluated resources on their topic, and published 'reviews' of these resources on the WWW. These reviews, which were originally designed as a means of instructional support for other forms of WWW publishing (discussed later in this paper), are authentic contributions to the WWW in their own right. Other high school students or educated lay persons might find these reviews to be a useful aid to their own research.

Disciplinary communication skills- the genres of science

Learning to communicate with other scientists is an important part of learning to do science, and the specific forms of disciplinary communication reflect the underlying sociocultural purposes of science (Berkenkotter & Huckin, 1995). The three forms of authentic student contributions to the WWW were also designed to teach disciplinary communication skills of science.

• Research reports on air pollution. The formats that scientists use to communicate with each other are prescribed enough to be considered a genre (or genres). These genres have developed over time to serve the needs of scientific discourse communities, (Swales, 1991), and to understand these genres is to understand some of the more valuable tools of science. In the air pollution project, we explicitly supported students' learning of this genre through a variety of means., such as in-class modeling and direct instruction.

• Multimedia resources on infectious diseases. Although high school students are probably more familiar with documents designed for the general public (textbooks, magazines, trade books) the rules for these

are not prescribed enough to be considered a separate genre. Instead, we taught students to communicate in these forms via a selected set of 'design principles', mostly having to do with organizational structure, design of graphics, and pairing of graphics and text.

• Reviews of existing resources. The WWW reviews we have published are not themselves a common format of scientific discourse. They do, however, focus student attention on elements of critical evaluation, examination of evidence, use of citation, 'meta' level analysis and synthesis which are valuable elements of scientific discourse. We also argue that such value-added contributions to a library may become more common and more important as decentralized, distributed digital libraries such as the WW become more prevalent (Bos, 1997).

Instructional support for students publishing for a WWW audience

We have developed a range of instructional supports to help students create artifacts for an audience of readers outside of the classroom.

Rhetorical methods

When we began this research three years ago, our ideas about how to help students write for an audience were borrowed from the field of composition studies, which often stresses knowledge of audience characteristics as a means to more effective writing. We sought especially to extend the ideas of Cohen and Riel (1989), who found that students wrote higher-qualities personal essays for an international audience of peers, because they explained themselves better for an audience whose knowledge level was different than that of their classroom teachers. Building on this, we identified four dimensions of audience characteristics which we felt were important for science writing, which were knowledge, role, relationship, and feedback (Bos, 1996). We hoped that we could help motivate and direct student writing in science by carefully selecting audiences according to these criteria, and by making these audiences and their characteristics salient to the students.

Over the course of six WWW-publishing projects we have realized that audience knowledge and awareness is not sufficient for most science writing. Without the specific skills of disciplinary communication, and knowledge of how these relate to the needs and characteristics of an audience, the audience knowledge alone is not usable by students. More recently we have focused on developing instructional support to help student bridge this gap between themselves and authentic outside audiences. In particular we will describe five methods of instructional support for WWW publishing (figure 1).

Instructional support	Purpose
1. Genre explanations Teachers explain the publishing genre explicitly in terms of needs of readers	Students see genre as a tool to communicate with readers, rather than a set of arbitrary constraints
2. WWW reviews Students write and publish critical WWW reviews of existing resources.	Students come to understand the needs and expectations of scientific readers by taking on that role.
3. Surveys of audience knowledge Student write and administer surveys to members of the intended audience.	The typical knowledge level, interests, and misconceptions of the intended audience are made explicit in the form of survey data.
4. Peer review Students evaluate each others' work according to assigned criteria.	Peer reviews may benefit both the student writing the review (developing their critical evaluation skills) and the student being reviewed (receiving knowledgeable feedback on their work).
5. Comments from outside readers An audience outside of the classroom is recruited to give feedback and comments on drafts of student work.	Outside comments can make the WWW publishing situation more authentic to students, and help students understand an outside reader's perspective.

figure 1. Five methods of instructional support for WWW publishing

1. Teachers explain genre or design principles in terms of audience needs.

Students cannot be expected to write effectively for an audience if they learn the disciplinary communication forms of science writing as sets of disconnected 'rules'. Instead, students need to understand genre forms as tools, which serve certain underlying purposes and which they can use to communicate with an audience that shares their understanding of the genre. Students cannot effectively write in a genre form unless they understand the underlying purposes of that form, and conversely, students can only write effectively for a scientific audience when they possess specific genre knowledge which they associate with different audience-related goals.

In teaching students how to write lab reports of their air pollution results, teachers conducted in-class modeling of student lab reports, and explained how the different parts of the model met the information needs of a scientific audience. Teachers explained how the fairly restrictive form of a lab report (introduction, methods, data, results, discussion) serves the needs of readers because it allows them to find the information in understood forms and in predictable places. Similarly, to prepare students to design a multimedia resource, we showed students exemplars and gave them a set of design principles that were explicitly tied to meeting audience needs. Examples of these multimedia design principles were, how to arrange 'cards' in a stack so that users can find the information they seek, and how to design graphics and text to reinforce each other, giving the user multiple representations to use to build their understanding. (A short version of the 'design principles' talk we gave to the classes is on-line at http://chs-web.neb.net/ diseases/about/ design_principles.html).

Some evidence that this was effective comes from post-project interviews on students' ideas about the lab report genre. When we gave students a copy of the air pollution project assignment criteria, and asked them why scientific laboratory reports follow prescribed formats, 10 out of 10 student groups explained the genre with some reference to audience needs. This demonstrates that students had, to some extent, internalized an explanation of the genre that was tied to a larger social context. To further test the effectiveness of this type of explaining, we examined verbal protocols of students designing and found that most student groups did occasionally refer to the needs of readers, although in only a few cases could we trace these reference directly back to the modeling and explanations we had done in class. We cannot yet determine whether or how students' knowledge of the genre affects their writing and design process.

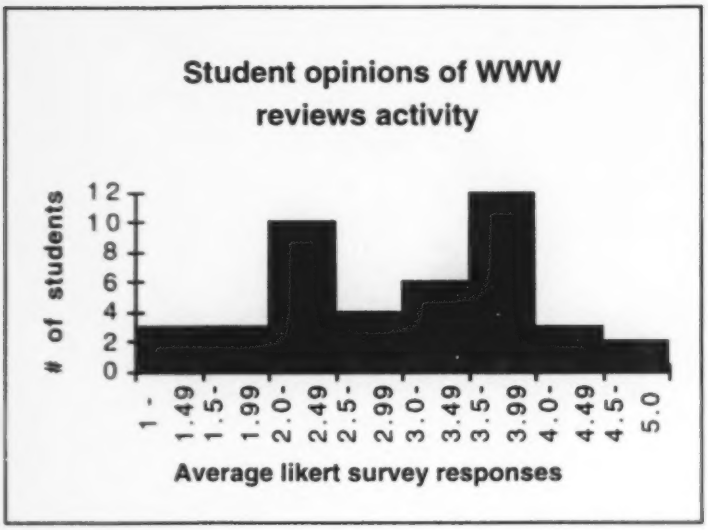
2. Students critically analyze existing resources and publish WWW resource reviews.

It is sometimes difficult for students to anticipate the needs of a scientific reader for things like proper citation, evidence for claims, and predictable organization structure because these are not things that students necessarily pay attention to when reading scientific material. Students can better understand the needs of a scientific reader if they first take on that role. We attempted to help students do this by having students write and publish critical evaluations of existing scientific resources. In the course of their own research, students were asked to identify a few good scientific resources, and write critical reviews, scaffolded by an in-class practice review, modeling, and a review 'form' with selected categories of analysis.

We focused student attention on different aspects of critical evaluation, depending on what kind of resource they were creating in the project. In the air pollution lab reports project, we focused students' attention on use of evidence for claims, citation of sources, and scientific organization. In the infectious diseases project, we focused more on multimedia design aspects of graphics and navigation, and selection of scientific content.

Content analysis of student-published reviews showed both promise and difficulty. We found that students had some difficulty in separating closely related means of establishing credibility such as use of evidence and use of citation. Students were more successful in making critical 'meta' level comments on the resources they reviewed, and in synthesizing comments into useful summaries.

Students' opinions on the WWW reviews activity was split. We asked students six likert survey items (appendix A) about whether they thought writing WWW reviews was valuable, and what they thought they learned from it. We found something of a bimodal split, with some students quite positive about all aspects of the review-writing, and some quite negative. We have not yet found any variable that seems to account for this split.



Bimodal distribution of student responses, averaged across six likert items, to questions about the worth of writing WWW reviews. Higher responses are more positive.

Examining the individual items, we found slightly positive average responses on two items. Students overall thought that writing WWW reviews made them more conscious of their own use of evidence and citation, (3.1 on 5 pt scale) and said that in designing their own WWW pages they tried to avoid some of the mistakes or bad features of resources they had reviewed (3.2 on 5 pt scale).

These WWW reviews are themselves a type of 'authentic' publishing task, because they are published on the WWW and are potentially useful 'value added' contributions for an audience seeking good resources on a topic (Bos, 1997.)

3. Students use surveys to create representations of audience knowledge.

To write effectively for an audience, a writer must have some conception of what the audience already knows, what their misconceptions might be, and what they would be interested in learning. While a professional writer might be able to mentally construct such a map of audience knowledge for themselves and use it to guide their writing, (Flowers, et. al, 1992), it is much more difficult for a high school writers to do so effectively. To make the audiences' prior knowledge more concrete in the infectious diseases project, we had students design and give surveys about their topic disease. Students asked five questions which they had written, and three questions which were written by the researcher and common to the entire class. The researcher-designed questions were specifically tailored to known popular misconceptions about infectious diseases. We tallied the results of some of these as a class, and found that the popular misconceptions did appear in survey results. For example, a multiple choice question about the difference between viruses and bacteria showed that the majority of respondents

could not tell the difference, and a substantial number indicated that a virus was a type of bacteria. Being able to concretize the level of audience knowledge as a survey result may help students direct the writing of their resources. Although studies of the infectious diseases project are not yet completed, interviews from last year's pilot project show that students did use survey results to guide their design decisions.

4. Students write peer reviews of each others' work.

In some project we have asked students to write peer-reviews of each others' project drafts. We believe that peer reviews may benefit both the student writing the reviews and the students whose project is being reviewed. Review-writers should have a chance to further sharpen their critical evaluation skills, and develop personal standards for writing and design. Students being reviewed should gain from feedback on their projects written by peers knowledgeable about the project and the design constraints. Despite this promise, it has been difficult in the past to get students to write critically or in depth about the content of each others' pages, and most peer reviews have focused on more surface level features. We have identified three key challenges, along with our current best solutions to these challenges.

• Students do not have the knowledge level to critique the content of peers' work on specialized topics. Thus, peer reviews tend to focus on more surface-level features. Current solution: ask peers to review each others' work in terms of design principles, not science content. Ask peers to take on the role of curious but naive users on the WWW, and decide whether they could learn from the resource effectively.

• Students do not want to risk alienating their classmates by writing negative comments. Current solution: design review form in such a way as to scaffold constructive criticism.

• Peer review tends to come near the end of the project, exactly when students are scrambling to finish their own projects, and students are often not inclined to put much thought or effort into reviewing a classmate's project. Current solution: extend the time between draft-due date and final-due date, and make the peer review a graded part of the project.

Analysis of the latest attempt to scaffold peer reviews (from the infectious diseases project) is currently underway.

5. Students receive comments from outside readers.

As with peer-review writing, this form of instructional support seems to hold great promise, but we are not satisfied with results to date. Comments from an outside audience should make the fact of WWW publishing more 'real' to students, and having an audience outside of the classroom may help students use writing strategies that are broader and more suited for the WWW.

Technologically, we have developed good methods for soliciting comments from outside readers. Students draft reports are published on the WWW a week or so before their final due date. Readers, who have been previously contacted by the project organizer, can then send in comments through an on-line form attached to the student WWW pages. The structure of the form allows the researchers to scaffold reader comments, and does not require readers to have an email account, only access to the WWW.

The current problems with soliciting comments from outside readers are not technological, they are in the pedagogical and social setting. First, students do not necessarily find getting feedback from outside readers to be very 'authentic', and for some students it is intimidating. Students were quite clear in post-project surveys after the air pollution project that they weren't really motivated by the presence of these outside readers. Student very seldom thought about readers while in the process of design, and neither did they often make changes to their draft documents based on reader comments. Again, we have identified a few key challenges for using outside reader comments as a means of instructional support.

• The timeline of draft- comment- revision is difficult. This was most problematic in the most recent project (air pollution laboratory reports). Although we found a group of scientists who agreed to write comments on student report drafts, the one-week window for writing these comments was too short for these busy professionals. Only a few students received comments in time to make any sort of revisions (had they been so inclined to make revisions.)

• Outside readers do not know how to write specific comments for high school students. When comparing the comments students received from outside readers to the comments received on the same drafts from their teachers, we were struck with how different they were. Teacher comments were very specifically tied to the project criteria, and were written in such a way that they were easily converted into document revisions. Comments from outside readers, who were, of course, not professional high school teachers, were much more difficult to comprehend by students. This could be another reason students rarely made changes based on feedback received.

• Commentary from outside the classroom is new to the culture of school. Heeding comments or advice from someone other than their teacher or a parent is not something students are accustomed to doing. If outside-reader comments are to be integrated into high school science classes, it may take more time and more regular exposure than was available in the WWW-publishing projects we have conducted so far.

We have a number of ideas for how to improve the use of outside reader comments. First, we think it may be beneficial to have students communicate with readers early on in the project, rather than wait until drafts are completed. In this way, there may be a more familiar relationship and possibly some shared understanding about the goals of the assignment. Second, we think it would be optimal to establish some kind of semi-permanent relationship between readers and a classroom of students, so that

the reader comments do not seem so 'out of the blue' to students and teachers. Third, we would like to develop procedures where students work collaboratively, perhaps in pairs, to try to understand reader comments and talk about how to turn these into revisions.

Although none of these ideas were implemented in the most recent project (infectious diseases) we hope to take up the challenge of scaffolding outside reader comments again in the future.

Discussion

Publishing student artifacts on the WWW can be a means to make student work more authentic, and to help students learn disciplinary communication skills. Some authentic projects that students can contribute to the WWW are, reports of their own data collection, secondary-source projects tailored for a specific audience, and critical reviews of existing resources.

In order to help students design artifacts for a WWW audience, we have used five methods of instructional support, with varying degrees of success. These methods are:

1. Teachers explain genre or design principles in terms of audience needs.
2. Students critically analyze existing resources and publish WWW resource reviews.
3. Students use surveys to create representations of audience knowledge.
4. Students write peer reviews of each others' work.
5. Students receive comments from outside readers.

Our ongoing research on student WWW publishing will evaluate the effectiveness of these instructional supports, as well as the overall effects of WWW publishing on student motivation and cognition.

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APPENDIX A

Six likert survey questions about WWW reviews, asked of students after the air pollution laboratory reports project.

WWW reviews

A. Do you think that writing and posting WWW reviews online was a worthwhile part of this project?
5 (definitely yes) 4 3 2 1 (definitely no)

B. Did reviewing other WWW pages help you become more analytical in your reading of scientific sources?
5 (definitely yes) 4 3 2 1 (definitely no)

C. Did any of the WWW pages you reviewed influence the way you designed your own WWW page?
5 (definitely yes) 4 3 2 1 (definitely no)

D. After reviewing other pages on the WWW, were you more conscious of your own use of evidence and citation (in your project reports)?
5 (definitely yes) 4 3 2 1 (definitely no)

E. After reviewing other pages on the WWW, were you more conscious of how other people might read the report your group was publishing?
5 (definitely yes) 4 3 2 1 (definitely no)

F. In designing your own WWW page, did you try to avoid some of the mistakes or bad features you saw on other WWW pages that you reviewed?
5 (definitely yes) 4 3 2 1 (definitely no)